§2. Deuterium Retention in Low-Activation Ferritic Steel under Low-Energy Deuterium Exposure

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Low-activation ferritic steel is a candidate for structure material in nuclear fusion devices. Hence, D-retention in the steel such as JLF1 [1] is important for designing the devices. We have studied D-retention in JLF1 under low-energy D-plasma exposure.

Mechanically polished JLF1 is exposed to deuterium-plasma generated by AC glow discharge of 1.5 KV in 53 Pa D_2 at room temperature, using the same method in [2]. Deuterium-plasma consists of 60 % D_3^+ and 40 % D_2^+ (D^+ can be negligible) [3]. Nuclear reaction, D(^{3}He,α)P, analysis (NRA) with 1.0 and 0.7 MeV $^3He^+$ was employed to obtain the D-retention. Here, the incident angle and detection angle of α-particles are 0^o and 20^o from the sample surface normal, respectively (NRA angle is 160^o measured from the incident beam direction). The composition was analyzed by means of 1 MeV ^{3}He RBS and the ratio of W over Fe (W/Fe) was obtained to be 0.6 %, in good agreement with that in literature [3]. For analysis of D-retention from NRA spectra, a small contribution of W is discarded, i.e., JLF1 is treated as Fe, as in the case of SUS.

Figure 1 shows the D-retention in JLF1 vs exposure time of deuterium-plasma. One sees that D-retention saturates at 30 min (fluence of D ~ 10^{18} cm^{-2}). Saturation behavior of D-retention in SUS316L was found to be similar to that in JLF1. D-retention at saturation is summarized in Table 1. The probing depth of 1.0 and 0.7 MeV ^{3}He was estimated to be 1.0 and 0.6 μm. According to preliminary results of the D's depth profile in JLF1, D's are presumably distributed near the surface within the depth resolution of ~40 nm. Hence, the difference of D-retention probed by between 1.0 and 0.7 MeV ^{3}He, i.e., 14x10^{15} cm^{-2}, are located in the depth of 0.6 to 1.0 μm and the D density relative to Fe density (N_{Fe}=8.48x10^{22} cm^{-3} or 7.86 g cm^{-3}) yields to 0.4 %, if D's are assumed to be uniformly distributed in the interior region. For both JLF1 and SUS316, oxygen was also analyzed by NRA, ^{16}O(d, α) ^{14}N, with 1.2 MeV d^+ ions and it appears that O's distributed in the region of ~60 nm from the surface and N_O/N_{Fe} is obtained to be ~5 %. Contribution of this amount of oxygen is not significant to D-retention (~10 %), since D-retention in Fe oxide probed by 1 MeV ^{3}He (probing depth of 1.3 μm) is 41 and 72x10^{15} cm^{-2} for α-Fe_2O_3, i.e., hematite (hexagonal corundum structure) and mixture of γ-Fe_2O_3 , i.e., maghemite (cubic spinel structure) and α-Fe_2O_3 [2]. For unpolished JLF1 (back surface of JLF1), slightly larger amount of D-retention was obtained, 37x10^{15} cm^{-2} (1 MeV ^{3}He) and 21x10^{15} cm^{-2} (0.7 MeV ^{3}He). Considerable reduction of D-retention in JLF1, roughly half in a week was observed even though the sample was kept in vacuum of 10^{-6} Torr. Measurements of D distribution in JLF1 and SUS, dynamic D-retention and thermal desorption of D are under way.

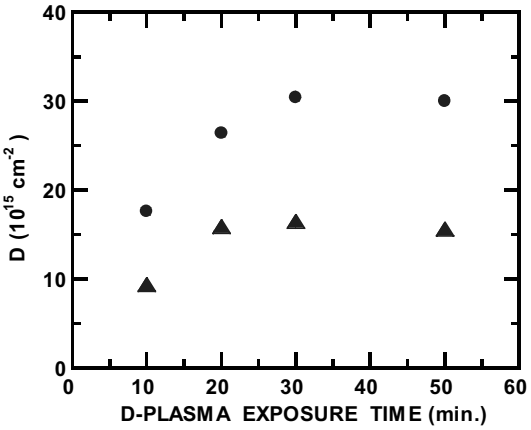

Fig. 1 D-retention in JLF1 vs exposure time to D-plasma (1.5 kV AC glow-discharge in 0.5 Torr D_2 obtained by 1 MeV ^{3}He(●) and 0.7 MeV ^{3}He (▲).

Table 1 Summary of D-retention at saturation in JLF1 and SUS (an estimated error of 15 %) probed by 1.0 and 0.7 MeV ^{3}He.

Sample	D-retention (10^{15} cm^{-2})	
	1.0 MeV	0.7 MeV
JLF1	30	16
SUS316L	36	24

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3. H. Sugai, H. Kojima, T. Mori, S. Aoki, T. Okuda, J. Nucl. Mater. 128/129(1984)169.